Utilization of T-O-E Framework in IoT for Food Quality Management: The Role of Perceived Risk in the Industry

Agnes Amaranggana Anindita
Faculty of Economics and Busines, Universitas Trisakti; Jakarta, Indonesia
E-Mail: 122012211039@std.trisakti.ac.id

Yolanda Masnita Siagian
Faculty of Economics and Busines, Universitas Trisakti; Jakarta, Indonesia
E-Mail: Yolandamasnita@trisakti.ac.id

Wahyuningsih Santosa
Faculty of Economics and Busines, Universitas Trisakti; Jakarta, Indonesia
E-Mail: Wahyuningsih@trisakti.ac.id

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ABSTRACT

This study aims to analyze factors within the Technological-Organizational-Environmental (T-O-E) framework influencing QM IoT adoption in the food industry, with perceived risk as a moderating variable. The population in this study are employees who work in the top eight food industry companies with the largest retail sales value in Indonesia. The research sample was selected using purposive sampling method of 186 respondents. Data analysis was conducted using partial least squares (PLS), which is a structural equation modeling (SEM). Based on the statistical test result, it was found that relative advantage, innovative capability, executive support, value chain partner pressure, and competitor pressure have a significant positive effect on QM IoT adoption intention. At the same time, complexity has a significant negative effect on QM IoT adoption intention. Perceived risk positively as a moderator that strengthens the influence between innovative capability, executive support, value chain partner pressure, and competitor pressure and QM IoT intention adoption. Meanwhile, perceived risk does not significantly as a moderator on relative advantage and complexity. The practical implications of these findings provide direction to decision-makers, policymakers, technology practitioners, and researchers in developing strategies to support the successful adoption of QM IoT.

Keywords*: Supply Chain, Quality Management, Adoption Intention, Food Industry.*

ABSTRAK

Penelitian ini bertujuan untuk menganalisis faktor-faktor dalam kerangka Technological-Organizational-Environmental (T-O-E) yang memengaruhi adopsi QM IoT di industri pangan, dengan persepsi risiko sebagai variabel moderasi. Populasi dalam penelitian ini adalah karyawan yang bekerja di delapan perusahaan industri pangan teratas dengan nilai penjualan eceran terbesar di Indonesia. Sampel penelitian dipilih menggunakan metode purposive sampling sebanyak 186 responden. Analisis data dilakukan dengan menggunakan partial least squares (PLS) yang merupakan model persamaan struktural (SEM). Berdasarkan hasil uji statistik, ditemukan bahwa keunggulan relatif, kapabilitas inovatif, dukungan eksekutif, tekanan mitra rantai nilai, dan tekanan pesaing memiliki pengaruh positif signifikan terhadap niat adopsi QM IoT. Sementara itu, kompleksitas memiliki pengaruh negatif signifikan terhadap niat adopsi QM IoT. Risiko yang dipersepsikan positif sebagai moderator yang memperkuat pengaruh antara kapabilitas inovatif, dukungan eksekutif, tekanan mitra rantai nilai, dan tekanan pesaing

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terhadap niat adopsi QM IoT. Risiko yang dipersepsikan tidak signifikan sebagai moderator pada keunggulan relatif dan kompleksitas. Implikasi praktis dari temuan ini memberikan arahan kepada para pengambil keputusan, pembuat kebijakan, praktisi teknologi, dan peneliti dalam mengembangkan strategi untuk mendukung keberhasilan adopsi QM IoT.

Kata kunci: *Rantai Pasokan, Manajemen Kualitas, Niat Adopsi, Industri Makanan.*

INTRODUCTION

A system of interconnected devices, equipped with sensors, and utilizing internet connections to collect data and information (Jones & Graham, 2018). IoT captures data from things without human intervention, transfers that data to its own computers via the internet and generates meaningful information. The system can track and trace everything, generate alerts about replacements, repairs, or recalls, and help reduce waste and costs (Ashton, 2009). IoT technology enables remote monitoring and control of physical objects across the network (Widodo et al., 2017). The era of globalization has encouraged the use of IoT in various industrial sectors, one of which is the food industry. Maintaining food quality and safety along the supply chain has become a very important challenge (Aung & Chang, 2014). Maintaining food quality and safety throughout the process in the food supply chain can use Quality Management Internet of Things (QM IoT). For example, the electric nose can be used in quality control to accept or reject incoming raw materials from some food industries, such as coffee, tea, fish and fruits (Peres et al., 2007).

In addition the Radio Frequency Identification (RFID) attached to cheese packaging can determine humidity, temperature, mold growth, biological contamination, acid corrosion, ammonia gas and other important data, such as milk type and manufacturer qualification (Kumar & Shankar, 2024; Kumar et al., 204; Wang, S., & Zhang, 2024). QM Usage IoT can help in efficiency, quality management, decision-making, and automated notifications for system users. Partners in the supply chain and consumers can also benefit from the use of QM IoT. Despite all the benefits, the adoption of IoT in developing countries is still in its infancy (Dagnaw et al., 2019). In addition, research on the adoption of QM IoT in the food industry is also still scarce. The lack of literature on the use of QM IoT in the food industry prompted the authors to conduct research to investigate the factors influencing the adoption of QM IoT in the food industry.

There are several novelties in this study. First, the purpose of this study is to confirm the inconsistency of the relative advantage to the intention adoption of QM IoT from several conflicting studies. Ahmad et al. (2020), stated that advantage positively affects the intention to adopt QM IoT. However, the research conducted by Opasvitayarux et al., 2022) stated that relative advantage does not affect the intention of adopting QM IoT. The inconsistency of research results can be caused by the existence of hidden factors that moderate the causal relationship between these factors (Umrani et al., 2018). This aspect has not been addressed in previous studies using the TOE framework for IoT adoption. According to Baron & Kenny (1986), the addition of variables moderation can be used when there are different research findings for the same variable. Moderation variables improve understanding of the problem and prevent misleading conclusions. Therefore, in this study perceived risk is added as a moderation variable.

According to food-related industries, several studies are exploring IoT adoption (Opasvitayarux et al., 2022). The existing literature discusses more about IoT adoption than QM IoT. QM IoT plays a crucial role in the food supply chain as it helps to strengthen food quality and safety within and among companies' supply chains. Based on the research from Opasvitayarux et al. (2022) to add research references on the adoption of QM IoT in the food industry, the authors project the purpose of the research is to test the factors that have an impact on the adoption of QM IoT in the food supply chain.

LITERATURE REVIEW

The theory used in this research is the Technology-Organization-Environment (TOE) framework introduced by Tomatzky & Fleischer (1990). The TOE theory states that innovation depends on the development of technology, organizational conditions, and the industrial environment. The TOE framework explains that an organization's intention to adopt new technology is influenced by these three contextual factors. The technological context refers to the characteristics of technology that affect the adoption process. The organizational context describes the influence of organizational resources on adoption decisions. The environmental context highlights the impact of the external environment and inter-organizational interactions where a business operates.

The technology context in this study is a relative advantage. This dimension refers to the extent to which potential users rate the innovation advantage higher or lower than the current way of performing the same task. Several studies have shown that relative advantage has a positive effect on IoT adoption, including studies on Chinese agricultural supply chains and Malaysian Halal agrofood SMEs (Lin et al., 2016; Ahmad et al., 2020). Relative advantage has demonstrated the importance of IoT adoption in several industries. Opasvitayarux et al. (2022) research states that the relative advantage has no impact on IoT adoption in Thailand's food supply chain industry. If a technology is considered to have a high relative advantage, then it is likely that individuals or organizations will feel greater benefits from the use of the technology (Liana & Fadli, 2023; Alpiana et al., 2024). In other words, the existence of relative advantage can increase perceived benefits or perceived benefits. For example, if an Internet of Things (IoT) technology innovation is considered more efficient, cost-effective, or provides a better experience compared to existing solutions, then an individual or organization can consider it to have a high relative advantage. As a result, it is likely to feel greater benefits.

H1: There is a positive and significant relative advantage effect on QM IoT adoption intention.

Complexity refers to the extent to which prospective adopters determine the understanding and difficulty of using innovations. It has a negative correlation with the adoption rate (Hwang et al., 2016). Complexity shows a negative influence on IoT adoption in several food supply chains, including in agriculture (Lin et al., 2016). This dimension refers to the ability of a company to develop new markets, products, services, production methods and sources of supply through an innovative strategic orientation (Wang & Ahmed, 2007). In the context of transportation and logistics, innovation capacity refers to a company's ability to innovate over the long term through intangible assets, such as research and development costs, patents and publications to adopt new technologies in a competitive market (Rey et al., 2021).

H2: There is a negative and significant influence of complexity on QM IoT adoption intention.
H3: There is a positive and significant influence of innovative capability on QM IoT adoption intention.

Top management support is an important part of an organization's decision to adopt new technologies. Top management support has a positive impact on the application of IoT in China's agricultural supply chain (Lin et al., 2016) and in manufacturing companies (Chan & Chong, 2013). According to Tiwari et al. (2023), the top management support factor is the most important factor in technology adoption.
H4: There is a positive and significant influence of executive support on QM IoT adoption intention.

Pressure comes from two main trading partners, namely suppliers and customers. Studies show that value chain partner pressure has a positive impact on IoT adoption in agricultural supply chains (Lin et al., 2016). Several studies show that competitive pressure has a positive effect on IoT adoption. For example, competitive pressures may affect the adoption of IoT in Taiwan's logistics industry (Hsu & Yeh, 2017). In addition, the level of competitive pressure in the agricultural product distribution industry and supply chain shows a significant positive relationship to RFID adoption (Lin et al., 2016).

H5: There is a positive and significant influence of value chain partner pressure on QM IoT adoption intention.
H6: There is a positive and significant influence of competitor pressure on QM IoT adoption intention.

Perceived risk refers to the nature and amount of risk felt by an organization when deciding on an action in an unknown situation. The role of moderation of perceived risk when applying the TOE framework to test IoT adoption in organizations has not received attention in information systems research. The reason for choosing perceived risk as a moderation variable in this study is that previous literature reports the role of perceived risk moderation in the application of various technological innovations. For example, Shen & Chiou (2010), it was found perceived risk moderated the relationship between the perception of ease of use and the intention to use internet services. In addition, the research conducted by Malik et al. (2021), also proves that there is a role in moderating perceived risk on TOE (Technology Organizational Environment) factors in the use of technology. The technological factors moderated perceived risk in the study are perceived benefits, perceived compatibility, perceived complexity, and perceived information transparency. The organizational factors that moderated perceived risk in the study were organization innovativeness, organization learning capability, and top management support. Meanwhile, the environmental factors moderated by perceived risk in the study were competition intensity, government support, and trading partner readiness. Therefore, the following hypothesis is proposed for the effect of perceived risk moderation on QM IoT adoption intention.

H7a: Perceived risk moderates the positive role of relative advantage and QM IoT adoption intention.
H7b: Perceived risk moderates the negative role of complexity and QM IoT adoption intention.
H7c: Perceived risk moderates the positive role of innovative capability and QM IoT adoption intention.
H7d: Perceived risk moderates the positive role of executive support and QM IoT adoption intention.
H7e: Perceived risk moderates the positive role of value chain partner pressure and QM IoT adoption intention.
H7f: Perceived risk moderates the positive role of competitor pressure and QM IoT adoption intention.

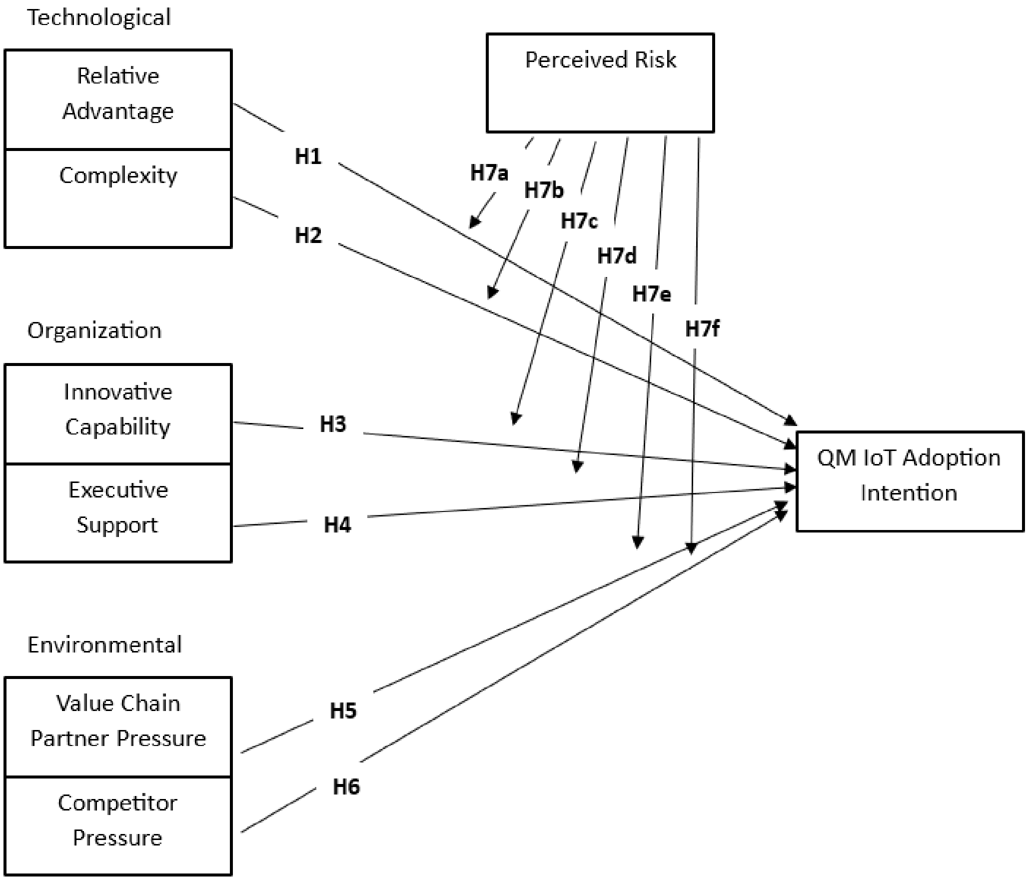

Figure 1. Research Framework

METHODS

This study adopts a quantitative research design, with primary data collected via a questionnaire distributed through Google Forms. The responses were measured using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The population consists of employees working in the top eight food industry companies in Indonesia, identified based on retail sales values. These companies were selected as they are representative for research on the adoption of Quality Management (QM) with Internet of Things (IoT) integration. The sample size of 186 respondents was determined using Hair's formula Hair et al. (2017) and selected through a purposive sampling method. This approach ensures that the sample is both relevant and adequate for the study's objectives. Respondents were chosen based on their knowledge and experience related to QM IoT practices within their organizations. For data analysis, the study employs Structural Equation Modeling-Partial Least Squares (SEM-PLS) using SmartPLS 3 software. SEM-PLS is particularly suitable for this research as it enables the simultaneous evaluation of relationships between variables, including latent constructs. It also allows for the incorporation and testing of moderating effects directly within the model, providing robust insights into the interactions among variables. By leveraging SEM-PLS, this study examines the factors influencing QM IoT adoption and assesses the moderating variables' impact on the relationships between constructs. The use of SmartPLS 3 facilitates the analysis of complex relationships, making it an effective tool for exploring the adoption dynamics of IoT in quality management practices within the Indonesian food industry. This approach ensures comprehensive and reliable results that contribute to the understanding of QM IoT integration.

RESULTS

The characteristics of the respondents from 186 employees included 74 males and 112 females. In terms of age distribution, 70 respondents (37.63%) were aged 31–40 years, followed by 63 respondents (33.87%) aged 20–30 years, 49 respondents (26.34%) aged 41–50 years, and 4 respondents (2.15%) aged over 50 years. The respondents also represented various fields of work, such as Information Technology (IT), quality, logistics and supply chain, production, and operations. The results of the outer model analysis with the convergent validity test show that the loading factor value for all indicator variables exceeds 0.70. If all indicators in the SEM-PLS model meet the requirements for convergent validity, discriminant validity, and reliability, then the SEM-PLS analysis results can be used to test the hypotheses in this research. Loading factor value greater than 0.70 is considered strong enough to validate and explain the underlying indicators.

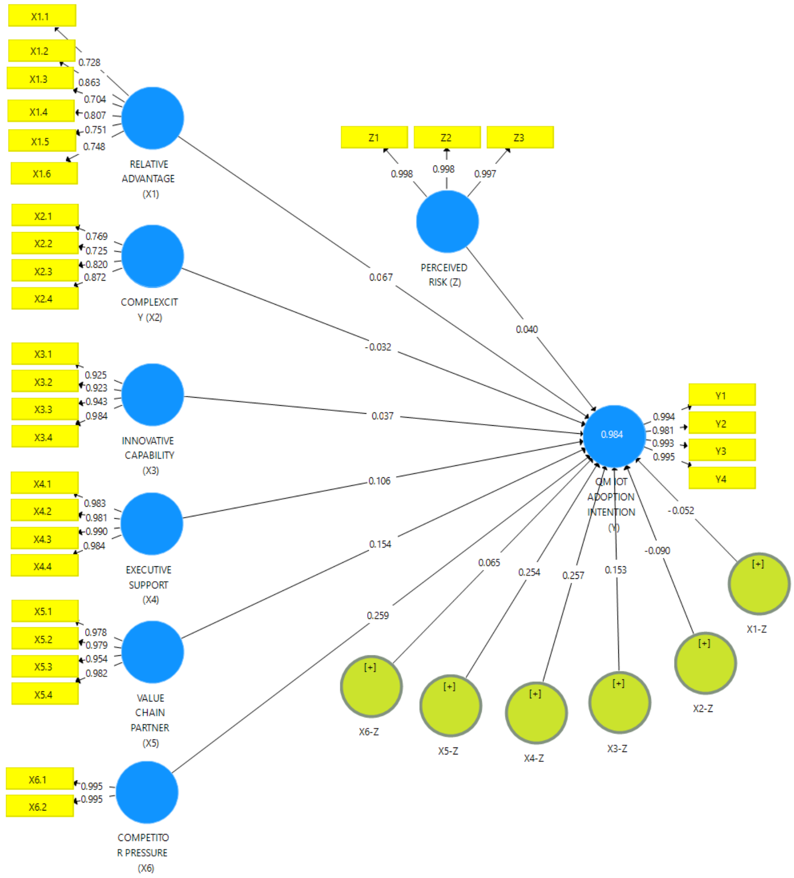

Figure 2. Loading Factor

According to Sarstedt et al. (2017), the AVE value of the variable > 0.5, it means that a good convergent validity condition has been met or indicates that the construct can explain 50% or more of the variation of the item. Furthermore, the validity of each latent variable was tested. This test is also referred to as a way of testing the unidimensionality of the model that has been developed. This test can be seen from the Cronbach Alpha and Composite Reality values of >0.7 (Muhson, 2022). The AVE value on the latent variable is >0.5. The value of Cronbach Alpha and Composite Reality >0.7 so that no unidimensionality problem was found in any latent variable studied.

Table 1. Composite Reliability Test

Variable	AVE	Cronbach's Alpha	Composite Reliability
Relative Advantage (X1)	0.703	0.864	0.757
Complexcity (X2)	0.758	0.790	0.755
Innovative Capability (X3)	0.766	0.893	0.928
Executive Support (X4)	0.969	0.989	0.992
Value Chain Partner Pressure (X5)	0.764	0.881	0.924
Competitor Pressure (X6)	0.989	0.989	0.995
Perceived Rizk (Z)	0.994	0.997	0.998
QM Iot Adoption Intention (Y)	0.982	0.994	0.995
X1-Z	1.000	1.000	1.000
X2-Z	1.000	1.000	1.000
X3-Z	1.000	1.000	1.000
X4-Z	1.000	1.000	1.000
X5-Z	1.000	1.000	1.000
X6-Z	1.000	1.000	1.000

Source: Processed data (2024)

In PLS-SEM 3.0, hypothesis testing is performed by evaluating the calculated t-value (T) derived from the data analysis against the critical t-value (t) obtained from the SPSS table. At a 5% significance level with the corresponding degrees of freedom, the critical t-value is 1.97294.

Table 2. Hypothesis Test

	Hypothesis	Path Coefficients	T Statistics	P Values	Information
H1	Relative Advantage → QM Iot Adoption Intention	0.067	1.986	0.035	Supported
H2	Complexcity → QM Iot Adoption Intention	-0.032	1.985	0.045	Supported
H3	Innovative Capability → QM Iot Adoption Intention	0.037	2.087	0.031	Supported
H4	Executive Support → QM Iot Adoption Intention	0.106	1.974	0.034	Supported
H5	Value Chain Partner Pressure→ QM Iot Adoption Intention	0.154	1.990	0.017	Supported
H6	Competitor Pressure → QM Iot Adoption Intention	0.259	2.174	0.030	Supported
H7a	X1-Z → QM Iot Adoption Intention	-0.052	1.997	0.049	Not Supported
H7b	X2-Z → QM Iot Adoption Intention	-0.090	2.428	0.015	Supported
H7c	X3-Z → QM Iot Adoption Intention	0.153	2.193	0.023	Supported
H7d	X4-Z → QM Iot Adoption Intention	0.257	1.982	0.021	Supported
H7e	X5-Z → QM Iot Adoption Intention	0.254	1.996	0.015	Supported
H7f	X6-Z → QM Iot Adoption Intention	0.065	2.024	0.045	Supported

Source: Processed data (2024)

The results of the data analysis indicate several key findings regarding the factors influencing Quality Management (QM) IoT adoption intention. The relative advantage significantly impacts QM IoT adoption intention, with a t-statistical value of 1.986 (greater than the t-table value of 1.97294), p-value of 0.035 (less than 0.050), and a positive path coefficient of 0.067. This suggests that the perceived benefits of QM IoT positively contribute to its adoption intention. Conversely, complexity negatively influences QM IoT adoption intention. The t-statistical value for this relationship is 1.985 (greater than the t-table value of 1.97294), with a p-value of 0.045 (greater than 0.050), and a negative path coefficient of 0.032. This implies that the higher the complexity, the lower the intention to adopt QM IoT.

Innovative capability positively affects QM IoT adoption intention, as indicated by a t-statistical value of 2.087 (greater than the t-table value of 1.97294), a p-value of 0.031 (less than 0.050), and a positive path coefficient of 0.037. This finding highlights the importance of an organization's ability to innovate in driving IoT adoption for quality management. Executive support also plays a significant role in influencing QM IoT adoption intention. The t-statistical value for this factor is 1.974 (greater than the t-table value of 1.97294), with a p-value of 0.034 (less than 0.050) and a positive path coefficient of 0.106. This underscores the importance of top management backing in facilitating IoT adoption.

Value chain partner pressure is another critical factor, with a t-statistical value of 1.990 (greater than the t-table value of 1.97294), a p-value of 0.017 (less than 0.050), and a positive path coefficient of 0.154. This suggests that external pressure from partners in the value chain encourages organizations to adopt QM IoT. Similarly, competitor pressure significantly influences adoption intention, with a t-statistical value of 2.174 (greater than the t-table value of 1.97294), a p-value of 0.030 (less than 0.050), and a positive path coefficient of 0.259. This indicates that competitive dynamics strongly drive the intention to adopt QM IoT. Regarding the moderating role of perceived risk, the analysis show that H7a is not supported, with a path coefficient of -0.052, t-statistic of 1.997, and a p-value of 0.049. The moderation effect of perceived risk is not observed in the relationship between relative advantage and QM IoT adoption intention. In contrast, hypotheses H7b, H7c, H7d, H7e, and H7f are supported.

DISCUSSION

This study demonstrates the relative advantage has a significant positive effect on QM adoption intention. The hypothesis that there is a positive and significant relative advantage influence on QM IoT adoption intention is supported. If a person or organization believes that the use of IoT provides a significant relative advantage compared to other solutions or technologies, then they are more likely to have the intention or desire to adopt IoT. The results of this study support previous research conducted by Ratnasari (2023), that the greater the relative advantage, the greater the technology will be adopted. Complexity has a significant negative effect on QM adoption intention. The hypothesis that there is a negative and significant influence of complexity on QM IoT adoption intention is supported. Organizations that find QM IoT difficult to use or understand are afraid of its implementation, which ultimately contributes to the low adoption of QM IoT. People with non-IT backgrounds find IoT more complex compared to those with IT knowledge. Therefore, organizations must be able to develop a better understanding of IoT. The results of this study support previous research conducted by Ahmad et al. (2020), that the complexity having a negative and statistically significant impact on the application of IoT in halal agro-food SMEs in Malaysia.

The results of the hypothesis test indicate that innovative capability has a significant positive effect on QM adoption intention. The hypothesis that there is a positive and significant relative advantage influence on QM IoT adoption intention is supported. Organizations that are able to acquire and apply new knowledge, are open to new ideas will be more likely to adopt QM IoT. Therefore, organizations must have mechanisms for developing new ideas in order to keep up with developments in the world that may be important to their business. The results of this study support previous research conducted by Lin et al. (2016), that higher organizational innovation leads to greater organizational transformation so that new technologies can be adopted. This study demonstrates that executive support has a significant positive effect on QM adoption intention. The hypothesis that there is a positive and significant influence of executive support on QM IoT adoption intention is supported. Without the support of top management, it is unlikely that QM IoT will be used in an organization. This is because the top leadership has the authority to approve strategic decisions such as the adoption of new technologies and allocate resources for them. Top management support must be determined and focused on the implementation of new technologies. The results of this study support previous research conducted by Hsu & Yeh (2017), that management support is the most important factor influencing IoT adoption because it helps to improve organizational readiness and expected benefits.

This study implies that value chain partner pressure has a significant positive effect on QM adoption intention. The hypothesis that there is a positive and significant influence of value chain partner pressure on QM IoT adoption intention is supported. The demand or encouragement from relevant parties in the supply chain, such as customers or suppliers, to integrate IoT in the quality management process can encourage organizations to be willing to adopt the technology. The results of this study support previous research conducted by Chan & Chong (2013), those who stated that pressure from suppliers and customers is a force that can influence technology adoption.

The study's findings also demonstrate that competitor pressure has a significant positive effect on QM adoption intention. The positive impact of competitor competition on QM IoT adoption implies that organizations want to stay competitive among their competitors. Competitive competition encourages organizations to find ways to grow and maintain their competitiveness. The hypothesis that there is a positive and significant influence of value chain partner pressure on QM IoT adoption intention is supported. The results of this study support previous research conducted by Lin et al. (2016), which states that pressure from competitors can encourage companies to adopt new technologies to improve services, gaining more competitive advantages.

Hypothesis 7a is not supported. The relative advantage path coefficient shows a significant negative influence on QM IoT intention adoption. This means that the high relative advantage is not enough to overcome the risks associated with the use of QM IoT. In the study Lin et al. (2016); Ahmad et al. (2020), stated that relative advantage positively affects the intention to adopt QM IoT. However, the research conducted by Opasvitayarux et al. (2022), stated that relative advantage does not affect QM IoT adoption intention. This proves that the inconsistency in previous research can be caused by a hidden factor, namely the role of perceived risk moderation. While the other variables show the same results as before the moderation variable was added. So, the hypothesis 7b,7c,7d,7e,7f is supported. This means that if the food industry has high innovation, good top management support, and pressure from partners and competitors, it will make the food industry feel better prepared to face the risks of using QM IoT. So risk is not always associated with negative things, but individuals who have a positive perception of risk or risk is used as an opportunity to achieve success, it will encourage interest in using QM IoT. Research conducted by Malik et al. (2021), found that perceived risk moderates the relationship between perceived compatibility, perceived information transparency, organizational innovativeness, and competition intensity.

CONCLUSION

This study found that before the influence of moderation, five factors including relative advantage, innovative capability, executive support, value chain partner pressure, and competitor pressure significantly had a positive effect on QM IoT intention adoption. This means that when the food industry views QM IoT as having a high relative advantage, the organization has innovation capabilities, receives top management support, and receives pressure from partners and competitors will make the food industry use QM IoT. Meanwhile, complexcity has a negative effect on QM IoT intention adoption. This means that the complexity of QM IoT will make the food industry hesitant to use QM IoT. After adding the perceived risk moderation variable, the relative advantage variable significantly had a negative impact on QM IoT intention adoption. This means that the high relative advantage is not enough to overcome the risks associated with the use of QM IoT. While the other variables give the same results as before the moderation variables were added. This means that if the food industry has high innovation, good top management support, and pressure from partners and competitors, it will make the food industry feel better prepared to face the risks of using QM IoT. The findings of this study can provide direction for decision makers and policymakers, technology practitioners, and researchers to develop strategies that contribute to the successful adoption of QM IoT. Company executives can also gain insights from this study to prepare for and accelerate the future deployment of QM IoT, while service providers can also know the important factors that companies are looking for in the food supply chain, so that service providers can better prepare and deliver additional alternative services.

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